SECTION 10: CONCLUSIONS

10) Conclusions

Hydrodynamic modeling of water mass dilution and dispersion was performed in a nearshore domain surrounding the HBGS which extends seaward to the edge of the continental shelf and alongshore from Seal Beach to Crystal Cove State Beach. (The model was developed at Scripps Institution of Oceanography for the US Navy's Coastal Water Clarity Program, was thoroughly peer reviewed, and has been calibrated and validated in numerous applications throughout the Southern California Bight). The model studied the ocean response to the proposed 50 mgd desalination plant using two separate modeling approaches: 1) event analyses of theoretical extreme cases, and 2) continuous long term simulations using the historical sequence ocean and plant operating variables. The latter approach was applied to two distinct historical periods: one resulting in 7,523 modeled solutions between 1980 and mid 2000 that characterized the period before HBGS was re-powered; the other involving 578 modeled solutions that characterized the post re-powering period using data collected between 1 January 2002 and 30 July 2003.

The event analysis involved some potential situations for operating the desalination plant when the generating plant is in *standby* mode and not producing electricity, or when it is operating at very low generating levels. We refer to these as "*low flow cases*" and they produce the highest in-the-pipe concentrations of sea salts from the desalination process. The most extreme of these low flow cases occurs when the generating plant is in *standby* mode and is providing no heating of the discharge water. The term "standby mode" broadly refers to a condition when the generating station is spinning an arbitrary collection of pumps with unheated discharge. But, not all possible combinations of pumps during "standby mode" are adequate for the desalination plant to produce product water at a rate of 50 mgd. We consider only those cases of standby mode when at least two circulation pumps are on-line (producing 126.7 mgd), because a minimum flow of 100 mgd is required to produce 50 mgd of product water. (No other pump combinations are available within the hydraulic architecture of the generating station that will provide flow rates between 100 mgd and 126.7 mgd). These low flow and standby mode cases are evaluated in combination with extreme conditions in the ocean environment involving tranquil, dry weather, La Niña type summer climate. By superimposing two conditions that seldom occur together (low plant flow cases and a calm ocean) the maximum potential impact of the desalination plant on the local ocean environment can be assessed because the dose level of sea salts is highest when the dilution of those salts by mixing and ventilation is lowest. The event analysis also evaluated an "*average case*" based on seasonal mean ocean conditions and average plant flow rates to determine the most likely degree of dilution of desalination plant discharge in nearshore waters.

Numerical modeling of the dilution and dispersion of concentrated seawater discharge from the proposed desalination plant has found that salinities of the receiving water become elevated above mean seawater salinities near the bottom in the immediate neighborhood of the outfall, and only then, when a number of extreme environmental and plant operating conditions occur simultaneously. Between 1980 and mid 2003, the low flow case resulting from only one generating unit being on line occurred 37% of the time while the unheated standby mode accounted for less than 1% of the occurrences. On the other hand, the occurrence of the ultra-benign environmental extremes is about 1 week every 3 to 7 years, primarily in summer during strong La Niña conditions. The joint probability for the simultaneous occurrence of these operating and environmental extremes is between 0.27% and 0.64% for the low-flow cases involving active power generation, and between 0.04% and 0.1% for the standby mode, depending on the length of ENSO cycles. In the model simulation of low flow case, these conditions were extended over 30 days, so that the recurrence interval for the low-flow results of this study are actually about 1 month every 13 to 31 years. The extreme operational conditions of the generating plant (low power generation and cooling water consumption) are mutually exclusive with these extreme environmental conditions. Because of this, dilution and dispersion of the concentrated seawater by-product were repeated using more nominal plant operating conditions and average climate conditions. Based on historical data representative of these conditions, the study made the following findings regarding dilution and dispersion of concentrated seawater by-product.

Dilution and Dispersion Before Completion of HBGS Re-Powering:

The dilution and dispersion results for the vent analyses are sumerized in Table 6. Maximum event impacts during the low flow conditions produce an initial vertical jet of high salinity water that broaches the surface and subsequently sinks to the seafloor, spreading outward from the base of the outfall tower. The highest salinities in the core of the discharge jet are 55.0 ppt at mid-depth (Figure 4.1), falling to 50.1 ppt on the sea surface directly above the outfall tower (Figure 4.2). The highest salinities on the seafloor are 48.3 ppt at the base of the outfall tower, rapidly decreasing with increasing distance from the tower (Figure 4.3). At most, 15.6 acres of benthic area are impacted by an increase in salinity that exceeds 36.9 ppt, that is 10% above the average ambient level of 33.5 ppt. Bottom salinities exceed ambient levels by more than 1% over an area of 263 acres. These elevated salinities effect only sandy, soft bottom habitat with no low relief exposed rocky substrate, and no surf grass or eel grass beds. The maximum area of pelagic habitat subjected to elevated salinity exceeding 10% of ambient is 18.3 acres while 151 acres of pelagic habitat experience an increase in salinity exceeding ambient by more than 1%. Minimum dilution of the concentrated seawater by-product at the shoreline is 32 to 1, (Figure 4.6) consistent with dye measurements from the recent study commissioned by the California Energy Commission (KOMEX, 2003). Two percent of the concentrated seawater by-product may be re-circulated in a sustained low flow case.

Dispersion and dilution contours of sea salts for the theoretical extreme of the standby mode are very similar to those shown in Figures 4.1 through 4.6. The absence of power plant heat produces a heavier combined discharge that is more slowly assimilated by the receiving waters. As a result, Table 6 indicates that the impacted benthic area around the outfall is marginally increased during standby mode to 18.2 acres, while the impacted pelagic area increases to 20.1 acres.

For average case events, the salinity in the water column directly above the discharge tower reaches 41.7 parts per thousand, (Figure 4.9), dropping to 38.3 ppt on the sea surface above the outfall tower (Figure 4.10). Maximum salinity on the sea bed is 37.6 ppt at the base of the outfall structure (Figure 4.11). The maximum area of benthic habitat subjected to a 10% increase in salinity is only 6.8 acres, while the area of pelagic habitat experiencing a similar increase is 8.3 acres. The benthic footprint of the 1% saline anomaly is 172 acres and the pelagic footprint is 130 acres. Except for the initial core of the discharge jet salinities under average conditions are everywhere within the range of natural variability. The percentage of re-circulated concentrated seawater by-product under average conditions is only 0.7%. Minimum dilution of the raw concentrate at the shorelineis 190 to 1 (Figure 4.14).

In vertical cross sections through the outfall in the cross-shore and longshore directions, the numerical hydrodynamic model finds that the saline plume emitted from the combined flows of the generating plant cooling water and the concentrated seawater of the desalination plant consists of a higher saline core between the surface and the bottom surrounded by a broad-scale salt wedge feature with weakly elevated salinities. The high-salinity core is formed in the immediate vicinity of the outfall by a jet of combined effluent discharged vertically upward from the top of the outfall tower. The core typically extends 40-50 meters away from the outfall with salinities of about 50 parts per thousand (ppt) for low flow-case conditions and 38 ppt for average case conditions. Maximum core salinity reaches 55.0 ppt in the discharge jet immediately above the outfall tower for low flow case and 41.7 ppt for average case. In the salt wedge surrounding the core, salinities vary from a couple to only a fraction of a ppt over ambient mean ocean salinities. Salt wedge salinities for both low flow and average case are within the envelope of natural variability. The salt wedge extends offshore for about 800 meters seaward of the outfall for low flow case and about 600 meters for average case. The total along shore dispersion of the detectable limits of the salt wedge is 2,150 meters for low flow case and 3,000 meters for average case, both with a downdrift bias toward the southeast. The predominant net current around the outfall is alongshore directed toward the southeast. Organisms drifting with this current will pass through the saline plume and be exposed to elevated salinities for varying periods of time depending on whether they pass through the narrow, high salinity core or the broad-scale salt wedge with its weakly elevated salinities. In a low flow case scenario drifting organisms would be subjected to maximum salinities of the core (53-55 ppt) for at most 7 minutes, but may linger in the salt wedge at 0. 1 ppt above ambient ocean salinities for as long as 10 hours (Figure 4.17). Exposure times at salinities 10 % above ambient levels would be 2.7 hours for the low flow case and 30 minutes under average conditions. Exposure to maximum core salinities under average conditions (40- 41.7 ppt) would be no more than 10 minutes while exposure to the weakly elevated salt wedge salinities would be no more than 7 hours.

In the long-term analysis, the hydrodynamic model solves for 7,523 daily outcomes from the uninterrupted monitoring data of ocean conditions and plant operating conditions that have occurred between 1980 and mid 2000. The objective of this portion of the analysis is to resolve all the intermediate cases that are possible between the low flow and average case event scenarios. In addition, the long term analysis examines the changes to the dispersion of the saline plume resulting from cold water discharges from HBGS occurring during standby mode when the ***Delta-T*** (ΔT) of the discharge stream is zero. (ΔT is the temperature difference between ocean water and plant discharge).

The modeled long-term outcomes were the result of 20.5 year long continuous time series of daily records for seven controlling operational and environmental inputs. These seven variables may be organized into ***boundary conditions*** and ***forcing functions***. The boundary conditions control the source strength (concentrated sea salts) and background conditions and include: ocean salinity, generating plant flow rates, ocean temperature, and ocean water levels. The period of record from 1980 until July 2000 was the longest period for which an unbroken record of all seven variables could be obtained and wave data was the limiting data base. However, the latter portion of this period was probably atypical from the present operational stand point because the generating station was under going re-fit and equipment modernization. Although there were instances of the plant operating with three and four generating units in the first seven years of the 1980- July 2000 period of record the preponderance of the record shows that the plant seldom supplied other than 2 different flow rates (127.6 or 253.4 mgd) most of the time. This historic 2 mode operational pattern introduced a ***bimodal*** statistical pattern into the model results (Figure 5.7).

Over the 20.5 year simulation period, the combined end-of-pipe salinity was found to vary from a minimum of 37 ppt with all 4 generating units on line, to a maximum of 56.4 ppt for cold water discharges during standby mode ($\triangle T = 0$ °C). The two predominantly recurring peaks in the probability density function for end-of -pipe salinity are centered at 41.6 ppt and 55.2 ppt, consistent with the average and low flow case values, respectively. The results are summarized in Table 7. The high salinity peak (low-flow rate peak) was attributed to the operation of only one generating unit, while the lower salinity peak (mid-flow rate peak) resulted from operation of two generating units. The salinities of the low-flow rate peak start out at 55 ppt in the water column above the outfall and fall off to 39 ppt at 150 meters away (the approximate outer limit of the 10 % salinity anomoly), accounting for between 42% and 48% of the modeled outcomes (Figure 5.7). On the sea floor, the low-flow rate operational condition (one generating unit) produces salinities that typically range from 47.5 ppt at the foot of the outfall to 37.0 ppt at 150 meters from the outfall (Figure 5.8) having the same recurrence rates as found in the water column. During times when two generating units (or more) were operated (mid-flow rate peak), salinities varied in the water column from 41.6 ppt at the outfall to 35.2 ppt at 150 meters away with a recurrence rate of 52% to 58%. On the sea floor, 2 generating unit operation (mid-flow rates) causes salinity to range from 38.6 ppt at the foot of the outfall to 34.8 ppt at 150 meters away with the same recurrence rate as for the water column.

Beyond 150 meters from the outfall, the probability density distribution for the discharge plume salinities no longer exhibits bi-modal character. Because the salinity contrast with the ambient water is greater for the low-flow rate peak, it becomes smeared by higher mixing rates promoted along stronger concentration gradients and it merges with the mid-flow rate peak in the distribution to form an asymmetric uni-modal distribution. The characteristics of this distribution are a mid-flow rate peak at lower salinities with a low-flow rate shoulder extending into higher salinity ranges. Salinities in the mid-flow rate peak of this distribution range from 34.6 ppt at 300 meters from the outfall and decay down to ambient ocean salinity at 2,000 meters from the outfall with a recurrence rate of 60% to 82% before reaching ambient ocean salinity levels. Salinities are only a fraction of a ppt greater on the bottom than in the water column over this range. For the low-flow rate shoulder of the probability density distribution, salinites vary from 36.2 ppt at a distance of 300 meters from the outfall, decaying to ambient salinity 2,000 meters away, with recurrence rate of 40% down to 18% before reaching ambient ocean salinity levels.

The bi-modal statistical bias imprinted on the model results by the historical plant flow rates throughout the re-fitting period appears to exhibit itself only in the nearfield of the outfall. The recurrence pattern of two distinct outcomes of approximately equal likelihood, one of high salinity and the other of more moderate salinity, is only apparent in the inner and outer core of the discharge plume, extending out to about 150 meters from the out fall (Figures 5.7 & 5.8). This is an area of about 17.5 acres. In the salt wedge portion of the plume from 500 meters out and beyond, operational patterns do not appear to alter the results by more than about 1 ppt, with salinities occurring between 34 ppt and 35 ppt or less regardless of historic operational tendencies. In the intermediate zone between 150 and 500 meters from the outfall, operational patterns cause salinity variations between 36 ppt or about 34.5 ppt. Such variations mean the difference between exceeding the upper limit of the natural ocean salinity range for this location, or not. In spite of the historical patterns there were no outcomes involving generation of electrical power that resulted in discharge salinities exceeding those of the low flow event scenario. Only for the relatively rare standby mode occurrences ($\Delta T = 0$ °C) did higher salinites occur, and these exceeded the low flow case by no more than 1 ppt and accounted for only 1% to 4% of all possible outcomes (Figures 5.7 & 5.8).

Dilution and Dispersion After Completion of HBGS Re-Powering:

After completion of the re-powering and shake-down of the AES Huntington Beach Generating Station in late 2001, higher generation levels and plant flow rates have been maintained than those observed for the late 1980's and throughout the 90's. To determine the implications of this shift in operational patterns on the probable dispersion and dilution of sea salts from the desalination plant, the long-term analysis methodology was repeated for the post re-powering period, 2 January 2002 - 30 July 2003. The dilution results for the post re-powering period are summarized in Table 8 with salinity probability density functions shown in Figures 5.25 and 5.26 at 150 meters away from the outfall. Comparing Figures 5.25 and

5.26 with Figure 5.7 with 5.8 we find that the low flow rate peak at is greatly reduced and represents only about 6% of the 578 daily outcomes during the post re-powering period. After re-powering, the histogram distribution at 150 meters from the outfall is predominantly unimodal and centered on 35 ppt with 92% of the outcomes giving salinities elevated less than the 10% above ambient. Beyond 150 meters away from the outfall, no outcomes from the 7 controlling variables during the post re-powering period give rise to salinities exceeding 40 ppt. Furthermore, no outcomes at any distance from the outfall during post re-powering conditions reach salinities as high as the low flow event cases. Thus, the operation of a 50 mgd desalination plant at AES Huntington Beach is unlikely to ever match or exceed the low flow case outcomes during the foreseeable future.

Source Water Quality at HBGS Intakes

In the remaining sections of this report (Sections 6-9) a hydrodynamic modeling study was conducted to determine if storm water and waste water are possible constituents of the source water at the intake to desalination plant. The storm water analysis considered flood discharges of the Santa Ana River and Talbert Channel watersheds and was also extended to include computations of recirculation of generating plant effluent between the offshore outfall and infall. Analysis of source water make-up further considered the dispersion of the wastefield from the 120" diameter deep ocean outfall located offshore of the Santa Ana River and operated by Orange County Sanitation District (OCSD).

The source water quality modeling was performed for a nearshore domain surrounding the AES Huntington Beach plant which extends alongshore from Seal Beach to Crystal Cove State Beach. The model was initialized for three sets of extreme environmental conditions to evaluate low flow case effects: 1) a wet weather El Niño winter condition to determine the quantity of ocean water and storm water from the Santa Ana River and the Talbert Channel reaching the AES intakes; and, 2) a summer El Niño condition when net transport by waves and currents flows northward to determine if the OCSD wastefield and Talbert Marsh tidal discharges can reach the AES intakes. The El Niño modeling scenarios provide a reasonable prediction of the maximum quantity of storm water runoff and OCSD wastefield reaching the AES intakes. The conclusions of the source water quality analysis are as follows:

Based on representative and historical data, the investigation provided a reasonable estimate of the likely mix of seawater and storm water at the AES Huntington Beach Generating Plant intakes during a period with extremely high storm runoff from both the Santa Ana River and Talbert Channel:

Over the 24-hour extreme runoff period, source water drawn at the infall is comprised of 0.0003% storm water from the Santa Ana River and Talbert Channel (Figure 7.5). Dilution of Santa Ana River and Talbert Channel storm water is 316 thousand to 1 at the depth of the infall velocity cap.

Over the seven-day extreme runoff period spanning the peak flood runoff event, source water drawn at the infall is comprised of only 0.0001% storm water from the Santa Ana River and Talbert Channel. Santa Ana River and Talbert Channel storm water is diluted to 1 million to 1 at the depth of the infall velocity cap.

For the duration of the 30-day extreme runoff period, the average make-up of the source water reaching the intakes would contain no detectable amount of storm water (Figure 7.11). Dilution of Santa Ana River and Talbert Channel storm water at the infall velocity cap is 10 million to 1.

For sustained high runoff and low flow operational conditions over a 7-day period of extreme wet weather, only a negligible amount of generating station storm water is re-circulated from the outfall to the infall. At most, 0.3% of the combined plant discharge is recirculated of which no more than 2.1% can be plant storm water based on NPDES permit restrictions. Hence plant storm water is at most 0.007% of the source water in a low flow case scenario (Figure 6.1). For maximum power plant generating levels, only 0.0004% of the source water can be expected to be recirculated plant storm water and about 0.003% for normal power generating levels. At all generation levels, the addition of the concentrated seawater by-product to the discharge of the AES power generating plant eliminates the positive buoyancy of the thermal plume and thereby reduces the size and temperature anomaly of the thermal footprint in the offshore waters. On average, the addition of concentrated sea water by-product to the thermal effluent of the generating station will reduce the size of the thermal plume by about 46%.

For low flow case summer El Niño conditions during flood tide (when typical coastal transport is most likely to reverse and flow northward), the wastefield of the OCSD deep outfall was found to disperse no closer than the 15 meter depth contour off Huntington Beach, about 2 km offshore (Figure 9.4). Dilution of the wastefield at the intake to AES Huntington Beach was calculated at 1 part per thirty million, indicating that even without the OCSD Disinfection Resolution of 2002, no total coliforms from the wastefield would be detectable in the source water. Similar calculations on the dispersion of tidal flux from the Talbert Marsh during spring tides found dilution of marsh waters to be 1 part per one hundred thousand at the intake, indicating that marsh coliforms would be nondetectable in source water (Figure 8.3).